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The relationship between output and asset prices: A time – and frequency – varying approach

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Abstract. *This paper employs wavelet analysis to examine the relationship between the U.S. output and asset prices. We use the theory of the monetary transmission mechanism to explain the relationship between them. Wavelet analysis takes the simultaneous examination of co-movement and causality into account in both the time and frequency domains. We do find the positive correlation between each two series in the time domain. More specifically, the output and asset prices including oil, stock and house prices exhibit positive co-movement in the most of the sample period. However, the relationship between output and gold prices is a positive correlation for only a few years. From the frequency domain, output and stock, house prices correlate with each other across different frequencies. In addition, output and oil prices correlate at middle (medium run) and higher (short run) frequencies and output and gold prices correlate at higher (short run) frequencies. These findings offer important implications analysing how to apply assets prices to forecast output and analysing periodic variation of economic growth and economical sustainability for policymakers and practitioners.*

Keywords: Gold Prices, Oil Prices, House Prices, Stock Prices, Output; Wavelet Analysis, Frequency Domain, Time Domain.

JEL Classification: C22, F36.

1. Introduction

This paper aims to provide some innovative insights on the relationship between the output and asset prices including gold, oil, house and stock prices in U.S. We use the theory of the monetary transmission mechanism to explain the relationship between them. In the U.S. economy, gold, oil, real estate and stock holdings comprise the principal components of wealth. Movements in their market values can dramatically affect the economic condition of families and business and, hence, affect the overall sustainable growth of the U.S. economy. In addition, as one of the important policy goal variables, output has been paid great attention by scholars and policymakers and is helpful for analyzing economic sustainability. For example, potential output is fundamental to the Phillips curve, which indicates the inverse relationship between unemployment and inflation. When real output rises above its equilibrium level, the economy is overheated and inflationary pressures amplify; when real output falls below it, the economy confronts the risk of disinflation. According to output and asset prices, forward-looking, useful information such as the trend of future economic activity, especially the future changes in output and/or inflation can be provided by asset prices (Stock and Watson, 2001; Gupta and Hartley, 2013). Furthermore, in order to achieving sustainable economic growth, it is bound to be analyzed the relationship between output and these asset prices. In the past decades, papers which analyze the relationship between output and these asset prices have emerged largely (Raja and Saumitra, 2009; Miller et al., 2011; Apergis et al., 2013; Kakali and Sajal, 2014, etc.). This paper employs wavelet analysis to identify co-movements and causality in the time and frequency domains between them in the U.S., deriving new insights and implications for investment strategies and market forecasts.

Oil is arguably an influential commodity with extraordinary ramifications for the real economy and financial markets and oil market is certainly the most influential commodity market. Furthermore, the U.S. acts as the biggest oil consumer and importer in the world and its oil industry is the pillar of the sustainable economy. So oil prices volatility in the U.S. are always an indispensable factor of studying economic development in the context of sustained economic growth and have a close relationship with output. In addition, oil acts as a non-renewable resource and is an important factor in achieving sustainable economic growth, so it is essential to analyse the relationship between output and oil prices. Forward-looking, Mork (1989) finds that the negative correlation between output and oil prices is in fact not statistically significant when the sample size of Hamilton's model is extended to include the oil collapse in 1986. However, the collapse of oil prices around the mid-1980s does not lead to an expansion in economic activity, and this triggers a new debate on the existence of an asymmetric relationship between output and oil prices. The asymmetric relationship suggests that oil prices shocks would have a larger negative impact on output than oil prices decline. Mork et al. (1994) have confirmed the validity of a similar type of asymmetric behavior for the OECD countries. Their results have revealed that increasing in oil prices seems to have a negative impact on economic growth in the U.S. to a larger extent, although the U.S. does not depend on imported oil compared to other developed countries, such as Germany, France, and Japan. In addition, Alessandro and Matteo (2009) find that the asymmetric effects of oil shocks on output growth do exist for the G-7 countries. Nazif and Ozelm (2013) suggest relationship between oil prices and macroeconomic activity is nonlinear and exhibits an asymmetric pattern, that is, oil price changes have a significant effect on inflation and output when the change exceeds a certain threshold level.

As for stocks, they own two main features, that is low transaction cost and high liquidity, and thus act as one of the most convenient investment vehicles. Sustainable capital markets are also critical of the economic sustainability. Recently, the financial crisis and Great Recession see a remarkable stock market crash, causing the U.S. and the world economy to suffer huge financial losses. So stocks prices in the U.S. are always an indispensable factor of achieving economic sustainable development and have a close relationship with output. Ram and Spencer (1983) think there is a negative relationship between real output and real stock prices. On the contrary, Fama (1981) and Raja and Saumitra (2009) obtain that there is a positive relationship between real output and real stock prices. In addition, the correlation between real economic activity and lagged real stock prices in the U.S. is positive and both statistically and economically significant by Barro (1990) and Schwert (1990). A similar relationship holds in Canada (Barro, 1990) and the G-7 (Choi et al., 1999).

Real estate has an important role for promoting the development of steel, home appliances, household goods and other industries and real estate is closely related to the stability of financial sector and the upgrading of consumption structure. In addition, housing market situation could have impact on the regional demographic changes, such as household formation, age group structure and household size structure. The demographic structure and trend are important features of social sustainability. In the U.S., housing assets is a widely held assets, housing wealth (non-housing wealth) is 37.78 percent (41.04 percent) of the U.S. household's total assets, and 47.93 percent (52.07 percent) of the U.S. household's total net worth. However, we know that the U.S. subprime mortgage crisis is a nationwide banking emergency that coincides with the U.S. recession of 2007:12-2009:06(1). It is triggered by a large decline in home prices, which spark a price bubble and collapse in the housing market and then lend fiasco and the financial crisis and destroy the economic sustainability. Many scholars argue that these events cause the dramatic changes in the behavior of financial and economic markets, even extending to global financial markets and economies. In addition, many studies have demonstrated the impacts of house market on economic through the investment effect, and that increase in house price will attract investment, as a result of capital gain expectation, and hence economic sustainable development. So policy makers generally agree that house prices play an important role in stimulating the growth or declining of an economy. For example, Miller et al. (2011) suggest that the strong housing market during the 2001 stock market crash may have increased the output and saved the U.S. economy from a severe recession and that the recent collapse of the housing market initiated the Great Recession. In recent years, a growing literature obtains the importance of the relationship between the housing market and the macro economy, suggesting that the interaction between house prices and economic growth imbeds important policy implications (Andrea and Claudio, 2010; Wendy et al., 2013). To identify whether house prices and output are integrated or segmented, a number of studies examine the spillover effects of the real house prices on consumption in the U.S. (Carroll, 2004; Campbell and Cocco, 2007; Mian and Sufi, 2011; Guerrieri and Iacoviello, 2013; etc.). Beltratti and Morana (2010) find that the US is an important source of global fluctuations for real housing prices. They think global supply-side shocks are an important determinant of G-7 house prices fluctuations. The linkage between real housing prices and macroeconomic developments is bidirectional, with investment showing in general a stronger reaction than consumption and output to housing prices shock. Moreover, Demary (2010) investigates the link between the real house prices and key macroeconomic variables, including output, and concludes that the real house prices significantly affect output. Miller et al., (2011) conclude that changes of house prices significantly affect Gross Metropolitan Product (GMP) growth, and the effect of predictable changes (the collateral effect) generate about three times the effect of unpredictable changes (the wealth effect). More recently, Apergis et al. (2013) find two-way causality between output and house prices across the U.S. metropolitan areas, but they require pre-testing for cointegration and stationarity. Besides, Wendy et al. (2013) find that while the real house prices leads real GDP per capita, in general (both during expansions and recessions), significant feedbacks also exist from real GDP per capita to the real house prices.

Besides, gold is thought as one of the most attractive investment options, although as a commodity it does not add much values to the productive capacity of the economy. Whereas currency depends on the strength of the economy, during times of financial crisis, such as a stock market crash, high inflation, recession, depreciating exchange rates, or other financial insecurity, gold is seen as a safe way to hold the value of one’s worth or to preserve the value of one’s assets and promote socio-economic development and stability in sovereign reserve portfolios. So the characteristic of gold lets many researchers to focus on the gold market and its influences on the economy. To analysis the distribution characteristics and nonlinear structure of gold prices, we can initially obtain the relationship between output and gold prices. For example, Manu and Rajnish (2012) find that when individual GDPs are regressed with gold prices, the gold prices are least correlated with Italy’s GDP but highly correlated with Brazil’s GDP. The gold prices are only moderately correlated with the U.S. GDP even though the U.S. has the world’s highest gold holdings. However, Kakali and Sajal (2014) investigate cointegrating relationship between gold import demand, gold prices and GDP for Indian economy, they also estimate short-run and long-run elasticities of gold import demand with respect to gold prices and GDP and find that they have cointegrating relationship.

As for methodology, wavelet analysis possesses significant advantages over conventional time-domain methods. It expands the underlying time series into a time-frequency space where researches can visualize both time- and frequency-varying information of the series in a highly intuitive way. Moreover, wavelet coherency and phase differences simultaneously assess how the correlation and causalities between the U.S. output and gold prices, oil prices, house prices, stock prices vary across frequencies and change over time in a time-frequency window. In this way, we can observe higher frequency (short run), middle frequency (medium run) and lower frequency (long run) relationships between each two series as well as possible structural changes and time-variations in such relationship. This method has been widely used in aspect of economic. For example, Goffe (1994) and Ramsey and Lampart (1998; 1998) have presented applications of wavelet analysis in economics and finance. More recent study, however, focuses on the correlation between stock markets as well as between energy commodities and macroeconomy (Rua and Nunes, 2009; Graham and Nikkinen, 2011; Aguiar-Conraria and Soares, 2011; McCarthy and Orlov, 2012; Loh, 2013; etc.). To the best of our knowledge, limited work so far simultaneously applies wavelet analysis to the relationship among output and these asset prices.

On one hand, the time- and frequency-varying features in such relationships can provide important practical implications for analysing the phenomenon of macroeconomic and achieving the economic sustainability. Time-varying co-movement means that the trends of variety and diversification benefits of macroeconomic evolve over time and, thus, economist should incorporate such effects when evaluating the trends, risk and returns of these macroeconomics. On the other hand, frequency-varying co-movement implies that economic analysts with different economical horizons should consider the co-movement at corresponding frequencies representing short, medium or long run so as to allocating economic phenomenon more effectively. What's more, the time- and frequency-varying features in the causality can also significantly affect the accuracy of market performance prediction and, hence, affect the regulatory benefits to policymakers and the comprehensive of analysing the phenomenon of economy and achieving the economic sustainability. For example, a recent study by Zhou (2010) stresses the importance of the time- and frequency-variation in the assessment of the relationship between the U.S. real estate and stocks markets.

Compared with papers in literature review, we conclude that there almost have no the research and related literatures that simultaneously analyze relationship between these four asset prices and output, and that simultaneously analyze dynamic correlation and causalities between them. In addition, methods[(2)] that most of previous studies use almost are, however, the conventional time-domain methods, they do not explore the frequency-variation in such relationships by these time-domain approaches while the time- and frequency-varying features in such relationships can provide important practical implications for portfolio management. Aiming at these problems, our paper utilizes a novel wavelet analysis to explore the relationship between output and asset prices in the U.S. in both the time and frequency domains with the help of the U.S. monthly data ranging from 1986:01 to 2015:03. Subsequently, we execute a simultaneous assessment of the co-movement and causal relationships between the U.S. output and these four asset prices.

This empirical study does find the positive co-movement between output and asset prices including oil prices, stock prices, house prices and gold prices indicated by the phase difference. This result is consistent with the results of theoretical derivation of the monetary transmission mechanism. More specifically, from the time domain, the output and asset prices including oil prices, stock prices and house prices exhibit positive co-movement in the most of the sample period. However, the relationship between output and gold prices is a positive correlation for only a few years. From the frequency domain, the output and stock prices, house prices correlate with each other at the short, medium and long run horizon. In addition, the results implies that combining output and oil prices achieves diversification generally at the short and medium run horizon, output and gold prices at the short run horizon.

This study proceeds as follows. Section 2 briefly introduces the theory of monetary transmission mechanism. Section 3 explains the methods about wavelet. Section 4 describes the corresponding data. Section 5 presents the empirical results. Section 6 concludes and policy implications.

2. The Theory of Monetary Transmission Mechanism & Wavelet Theory and Methods

Tobin's q-theory (Tobin, 1969) offers an important mechanism for how movements in asset prices could affect the economy. Tobin's q is defined as the market value of firms divided by the replacement cost of capital. Q is high, that is, the market price of firms is high relative to the replacement cost of capital, and new plant and equipment capital is cheap relative to the market value of firms. Companies can then issue asset and get a high price for it relative to the cost of the facilities and equipment they are buying. Investment spending will rise because firms can now buy a lot of new investment goods with only a small issue of asset.

The key of the Tobin q-model is that a link exists between stock prices and investment spending. Higher stock prices will lead to higher investment spending, leads to the following transmission mechanism which can be described by the following schematic:

$$P_s \uparrow \Rightarrow q \uparrow \Rightarrow I \uparrow \Rightarrow Y \uparrow ,$$

where a rise in stock prices($P_s \uparrow$) can increase company's profit, that is, raises q ($q \uparrow$) and then raises investment ($I \uparrow$), thereby leading to an increase in aggregate demand and a rise in output($Y \uparrow$).

McCarthy and Pench (2001) suggest that the model of housing expenditure is really a variant of Tobin's q-theory in which q for housing investment is the price of housing relative to its replacement cost. With a higher price of housing ($P_h \uparrow$) relative to its construction cost, construction firms find it more profitable to build housing, and thus housing expenditure will rise ($H \uparrow$) and so aggregate demand will rise ($Y \uparrow$).This transmission mechanism is then described by the following schematic.

$$P_h \uparrow \Rightarrow H \uparrow \Rightarrow Y \uparrow .$$

Analysis of the monetary transmission mechanism of fluctuations in oil prices on the impact of output is that raise of oil prices (denoted by $P_o \uparrow$) can stimulate surging in inflation ($P \uparrow$) and then we infer interest rate will fall ($r \downarrow$) according to Fisher equation (The Fisher Equation is used in economic theory to explain the relationship between interest rates and inflation. The theories behind it were introduced by American economist Irving Fisher.), leading to a drop in the exchange rate ($E \downarrow$), the lower value of the domestic currency makes domestic goods cheaper than foreign goods, thereby causing a rise in net exports ($NX \uparrow$) and hence in aggregate spending ($Y \uparrow$). That is,

$P_o \uparrow \Rightarrow P \uparrow \Rightarrow r \downarrow \Rightarrow E \downarrow \Rightarrow EX \uparrow \Rightarrow Y \uparrow$.

Gold prices rise (denoted by $G \uparrow$), which lowers interest rates ($r \downarrow$), which raises investment ($I \uparrow$), thereby leading to an increase in aggregate demand and a rise in output ($Y \uparrow$).This transmission mechanism is then described by the following schematic.

$G \uparrow \Rightarrow r \downarrow \Rightarrow I \uparrow \Rightarrow Y \uparrow$.

Wavelet analysis which is an alternative to the well-known Fourier analysis has stemmed from in the mid-1980s. In terms of methods, wavelet analysis that takes the simultaneous examination of co-movement and causality into account in both the time and frequency domains owns significant advantages over conventional time-domain methods. In spite of Fourier analysis can discover how relations vary across frequencies using spectral techniques, the time-localized information is discarded by the Fourier-transform analysis. In addition, Fourier analysis is no longer in force for non-stationary series. In contrast, wavelet analysis conducts the estimation of spectral characteristics of a time series as a function of time [38]. Moreover, it exhibits a significant advantage compared with Fourier analysis for non-stationary or locally stationary series (Roueff and Sachs, 2011).

2.1. Continuous wavelet transform

Using the wavelet transform, a time series is decomposed into some basis wavelets, which are stretched and translated versions of a given mother wavelet localized in both the time and frequency domains. In this way, the time series expands into a time-frequency space where its oscillations appear in a highly intuitive way. At this point, two kinds of wavelet transforms, discrete wavelet transforms (DWT) and continuous wavelet transforms (CWT), usually exist. The DWT can reduce noise and decomposes data whereas the CWT extracts information and detects data self-similarities (Grinsted et al., 2004; Loh, 2013)(3). In this paper, we choose the CWT to decompose the concerned series into wavelets. The CWT of a given time series $x(t)$ is defined as a convolution type:

$$W_x(u,s) = \int_{-\infty}^{+\infty} x(t)\psi_{u,s}^{*}(t)dt \qquad (1)$$

where $\psi_{\tau,s}^{*}(t)$ is the complex conjugate function of $\psi_{\tau,s}(t)$ which is called the basis wavelet function. As has been noted, the basis wavelet comes from a given mother wavelet, represented by $\psi(t)$, that is:

$$\psi_{u,s}(t) = \frac{1}{\sqrt{s}}\psi(\frac{t-u}{s}) \qquad (2)$$

where s is the wavelet scale that controls how the mother wavelet is stretched or dilated, and u is the location parameter that determines the exact position of the wavelet. By changing the scale parameter (s) and translating along the localized time index (u). In addition, we define $x(t)$ as:

$$x(t) = C_{\psi}^{-1}\int_{0}^{+\infty}\left[\int_{-\infty}^{+\infty} W_x(u,s)\psi_{u,s}(t)du\right]\frac{ds}{s^2}, \quad s>0 \qquad (3)$$

Torrence and Compo (1998) suggest one can construct a photo representing how the amplitudes of $x(t)$ vary across scale and over time.

Three conditions must be fulfilled in a mother wavelet of the CWT: First, $\int_{-\infty}^{+\infty}\psi(t)dt=0$, that is, the mean of $\psi(t)$ must equal zero, which makes sure that it oscillates across positive and negative values near zero and, thus, is nonzero locally; Second, $\int_{-\infty}^{+\infty}\psi^2(t)dt=1$, that is, its quadratic sum must equal one, which suggests a limitation to an interval of time; Third, it must satisfy the admissibility condition, that is:

$$0<C_{\varphi}=\int_{0}^{+\infty}\frac{\left|\tilde{f}(\omega)\right|}{\omega}d\omega<+\infty \tag{4}$$

where $\tilde{f}(\omega)$ is the Fourier transform of the mother wavelet $\psi(t)$.

In wavelet theory, the most popular and applicable mother wavelet for feature extraction is the Morlet wavelet(4) which is introduced by Grossman and Morlet (1984), that is:

$$\psi^{M}(t)=\pi^{-1/4}e^{i\omega_0 t}e^{-t^2/2} \tag{5}$$

where $\pi^{-1/4}$ ensures the second condition is satisfied and $e^{-t^2/2}$ ensures the third condition is satisfied. According to Aguiar-Conraria and Soares (2013), the Fourier frequency $f(s)$ is given by $f(s)=\omega_0/2\pi s$ [43]. In particular, when the dimensionless frequency satisfies $\omega_0=6$, the Morlet wavelet attains optimal trade-off between time and frequency localization. Therefore, this paper supposes $\omega_0=6$, we obtain the relationship between the wavelet scale S and the Fourier frequency f through derivation:

$$f=6/2\pi s\approx 1/s \tag{6}$$

As a result, equation (6) implies that $x(t)$ decomposes into a joint time-frequency plane where the shorter wavelet scale corresponds to the higher frequency and the longer wavelet scale corresponds to the lower frequency. Moreover, since the Morlet wavelet is a complex wavelet, the CWT is split into real and imaginary parts, we can calculate the amplitudes and phases of the CWT for further estimations of wavelet power spectrum, wavelet coherency and phase difference.

2.2. Wavelet power spectrum

In wavelet theory and practice, the wavelet power spectrum of one series $x(t)$, namely the auto-wavelet power spectrum, is defined as equation (3). For simplicity, we simply defined $x(t)$ as $\left|W_x(u,s)\right|^2$. It introduces a measure of the localized volatility of $x(t)$ at each scale or frequency. Furthermore, since Hudgins et al. (1993) first define $W_x(u,s)$

and $W_x(u,s)$ which are the continuous wavelet transforms of $x(t)$ and $y(t)$ as $W_{xy}(u,s)=W_x(u,s)W_y^*(u,s)$, where the symbol * denotes a complex conjugate. So the cross-wavelet power spectrum is accordingly written as:

$$\left|W_{xy}(u,s)\right|^2=\left|W_x(u,s)\right|^2\left|W_y^*(u,s)\right|^2 \tag{7}$$

The function of cross-wavelet power spectrum is give a measure of the localized covariance between $x(t)$ and $y(t)$ for the specified frequency.

In this paper, the wavelet power spectrum depicts the localized volatility of the U.S. output and these four asset prices as well as estimates the wavelet coherency between each two. Note that, in wavelet power spectrum plots, the wavelet power of these economic variables is marked by color bars between 0 and 1 on the right side, where red colors correspond to high power while blue colors correspond to low power. That is, the color bars also correspond to the localized volatility of the underlying series.

2.3. Wavelet coherency

Wavelet coherency allows for a three-dimensional analysis, which simultaneously thinks about the time and frequency components and the strength of correlation between the time-series components. In this way, we can observe both the time- and frequency-variations of the correlation between series in a time-frequency space. Consequently, the wavelet coherency gets a more accurate results of co-movement between the U.S. output and asset prices in comparison to the conventional correlation analysis as well as the dynamic conditional correlation analysis (Zhou, 2010; Liow, 2012; Loh, 2013). Following the approach of Torrence and Webster (1999), we define wavelet coherency by using the cross-wavelet and auto-wavelet power spectrums as follows:

$$R^2(u,s)=\frac{\left|S\left(s^{-1}W_{xy}(u,s)\right)\right|^2}{S\left(s^{-1}\left|W_x(u,s)\right|^2\right)S\left(s^{-1}\left|W_y(u,s)\right|^2\right)} \tag{8}$$

Here, we calculate wavelet coherency with the above squared type and the smoothing operator S [(5)]. It, by this way, gives a quantity between 0 and 1 in a time-frequency window. Zero coherency implies no co-movement between the U.S. output and asset prices while the highest coherency indicates the strongest correlation among them. In the empirical section, we also clearly mark the squared wavelet coherency with color bars on the right side of the wavelet coherency plots, where red colors correspond to a strong co-movement whereas blue colors correspond to a weak co-movement.

2.4. Phase difference

Because the wavelet coherency is squared, that is, we can only compute positive number, we can't distinguish between positive and negative correlation. Therefore, we subsequently use the phase difference to judge positive or negative correlation as well as the lead-lag relationships among them. According to Bloomfield et al. (2004), the phase difference characterizes phase relationship between $x(t)$ and $y(t)$ as follows:

$$\phi_{xy}(u,s) = \tan^{-1}\left(\frac{\Gamma\left\{S\left(s^{-1}W_{xy}\left(u,s\right)\right)\right\}}{\mathrm{N}\left\{S\left(s^{-1}W_{xy}\left(u,s\right)\right)\right\}}\right), with\ \ \phi_{xy} \in \left[-\pi,\pi\right] \tag{9}$$

where Γ and N are the imaginary and real parts of the smoothed cross-wavelet transform, respectively.

A phase difference of zero implies that the two underlying series move together whereas a phase difference of $\pi\left(-\pi\right)$ indicates that they move in the opposite direction. On one hand, if $\phi_{xy}(u,s) \in \left(-\pi/2,\pi/2\right)$, it suggests that the series move in phase (positively co-movement). On the country, if $\phi_{xy}(u,s) \in \left(\pi/2,\pi\right)$ or $\phi_{xy}(u,s) \in \left(-\pi,-\pi/2\right)$, indicating that the series move out of phase (negatively co-movement). On the other hand, if $\phi_{xy}(u,s) \in \left(0,\pi/2\right)$ or $\phi_{xy}(u,s) \in \left(-\pi,-\pi/2\right)$, it suggests that the series $x\left(t\right)$ leads the series $y\left(t\right)$. While, if $\phi_{xy}(u,s) \in \left(-\pi/2,0\right)$ or $\phi_{xy}(u,s) \in \left(\pi/2,\pi\right)$, then the series $y\left(t\right)$ leads the series $x\left(t\right)$. In addition, the phase difference can also indicate causality between $x\left(t\right)$ and $y\left(t\right)$ in both the time and frequency domains. As a consequence, it dominates the conventional Granger causality test, which assumes that a single causal link holds for the whole sample period as well as at each frequency (Grinsted et al., 2004; Tiwari et al., 2013). For example, if $x\left(t\right)$ leads $y\left(t\right)$, then it suggests a causal relationship running from $x\left(t\right)$ to $y\left(t\right)$ at a particular time and frequency.

3. Data and Empirical Results

The aim of this paper is to examine the relationship between output and asset prices including gold prices, oil prices, house prices and stock prices in the U.S. and employs the U.S. monthly data ranging from 1986:01 to 2015:03. This sample period covers a series of different market booms and busts in the U.S, as well as different economic recessions and expansions, creating substantial volatility that may provide different outcomes from other less-volatile periods. We use the monthly industrial production index to measure the U.S. output(6) and use the prices of WTI(7) to get the oil prices. We obtain the Consumer Price Index (CPI), stock prices and Industrial Production Index (INDPRO) from the online data segment of Robert J. Shiller's website(8). In addition, we get the monthly gold prices series from The London Gold Market Fixing Limited (TLGMFL), the monthly house prices(9) series and the monthly oil prices from Federal Reserve Bank of St. Louis. To get the data of real industrial production index, the real oil prices, the real stock prices, real house prices and real gold prices, we make the corresponding and original time series to divide the U.S. consumer price index. In order to obtain more accurate results, all the original data is processed by taking natural logarithms and taking first-differences of the concerned variables, to correct for potential heteroscedasticity and dimensional difference between series and to get month-on-month growth rates of real stock prices, real house prices, real gold prices, real oil prices and real output (using industrial production index).

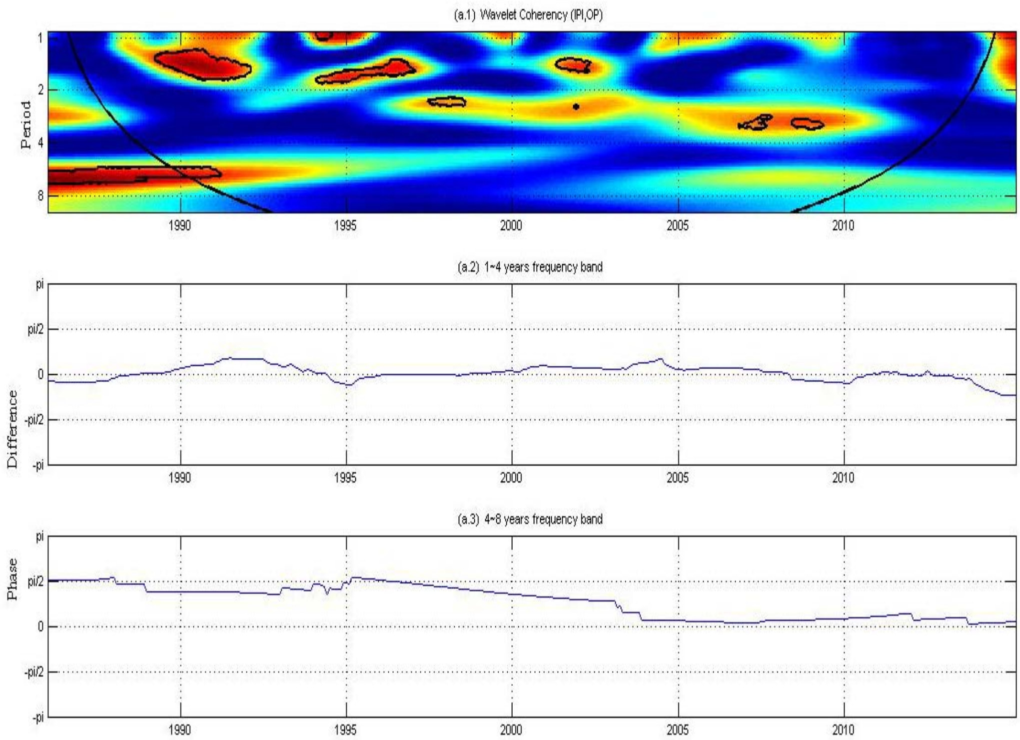
An "island" which is surrounded by a black coil on the left-hand side of part (a.1) in figures 1-4, shows the significant correlation between each two series at a particular time-frequency (this paper hypothesizes the significant level equals to 5%). The cone-shaped zone at the below of two symmetrical black lines points out the correlation between output and asset prices is easily affected by the edge effect in this region. Color bars on the right-hand side of the wavelet coherency plots display the extent of the correlation between them. In addition, the plot (a.2) shows phase difference between them in the 1 to 4 years' time-frequency and the plot (a.3) states the phase difference between them in the 4 to 8 years' time-frequency. In order to observing relationship between them better, this paper defines the 1 to 2 years' time-frequency as short run, the 2 to 4 years' time-frequency as medium run and the 4 to 8 years' time-frequency as long run.

3.1. The relationship between U.S. output and oil prices

Figure 1 shows positive and strong correlation between the U.S. output and oil price. The co-movement, however, does depend on the frequency and is unstable over the period 1986 to 2015, which largely unanimous with Mork (1990) who suggests a negative co-movement between output and oil prices. More specifically, from 1989-1992, the U.S. output and oil prices show an average coherency of 0.9 across the 1-2 year frequency band with an in-phase relation indicated by the phase difference between 0 and $\pi/2$, implying a high degree of co-movement, it, meantime, means that the U.S. output leads oil prices in the short run. In other words, the change of the U.S. output is an important factor which impacts the oil prices. Investigating its reason, we find most of the 1990s in the U.S. as a strong sustained economic growth period and bring with it the oil prices rise from 1989-1992. The result from 1994-1996 is just opposite, that is, the change of oil prices is an important factor which impacts the U.S. output. Then, there is an average coherency of 0.6 with an in-phase relation indicated by the phase difference between 0 and $\pi/2$ across the 2-4 year frequency band during 2002-2004, it shows that the change of the U.S. output, in the context of sustained economic growth, is an important factor which impacts oil prices in the medium run. In this sense, the wave of output has been lagging effected by the earlier period of oil prices in 2002-2004. It is in line with the U.S. situation. For example, the sustained real economic growth continued in 2002 and 2004, when, due to a hike in total factor productivity and industrial capacity utilization, increasing external competitiveness and decreasing unemployment, the output gap closed and the economy subsequently overheated, growing much faster than implied by its potential rate of growth and expediting the oil prices. Furthermore, the output and oil prices show an average coherency of 0.8 across the 1-10 year frequency band during 2006-2015, more specifically, between $-\pi/2$ and 0 from 2008-2011 in 1-4 years frequency band and from 2006-2014 in 4-8 years frequency band. It suggests, in this period, oil prices mostly lead the U.S. output not only in the short run, but also in medium run, the most important is in the long run. That is, the wave of oil prices is an important reason which impacts the U.S. output in the short run, in the medium run and in the long run. However, we find that the output leads oil prices in the medium run indicated during 2006-2008, it is helpful to explain the realistic economic phenomena that the outlook for the U.S. output increases from 1994-2000, a large portion of capital goes to the crude oil markets and pushes up oil prices from 2006-2008. These results are consistent with the results of theoretical derivation of the monetary transmission mechanism, that is, when oil prices rise, the output will rise and vice versa.

Figure 1. *The wavelet coherency and phase difference between the U.S. output and oil price*

The y-axis refers to the frequencies (measured in mouths); the x-axis refers to the time period over the period 1986:1-2015:3. The color bar on the right side corresponds to the strength of correlation at each frequency.

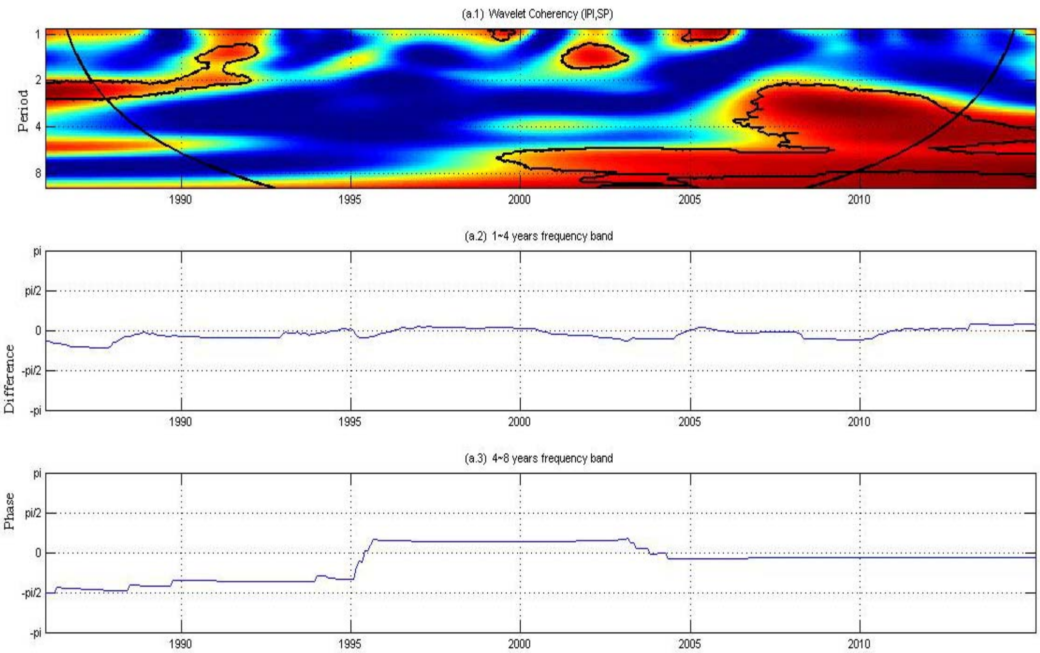


3.2. The relationship between U.S. output and stock prices

Figure 2 shows positive and strong correlation between the U.S. output and stock prices. This finding is according with Carlstrom et al. (2002), which document a two-way causality between stock market and output. When stock prices are climbing, it is often easier for companies and business to obtain financing. In the meanwhile, companies are more likely to expand and hire more employees and thus national output will raise. From 1987-1992, we find that they show an average coherency of 0.8 across the 1-4 year frequency band and they have a high degree of positive co-movement, which largely unanimous with Barro (1990) as well as Schwert (1990) who suggest a positive co-movement between output and stock prices, and the output will vary with our changes in the stock prices in the short run and in the medium. At the same time, this phase difference is suggest that stock prices affect the U.S. output. Then, we discover that output and stock prices show an average coherency of 0.8 in the period 1995-2003. During this time we can obviously see that they show stock prices will vary with the changes in output in the long run. It is in line with the U.S. situation that most of the 1990s in the U.S. as a strong sustained economic growth period. During 1993-2000, the U.S. exhibited the best economic performance of the past decades. From 1995-2000, stock prices have been rising owing to the lagging influence of output. Furthermore, the U.S. output will vary with the changes in stock prices for the short, medium and long run during 2003-2013. Furkan et al. (2014) explain that economic expansion may signal appropriate time for stock investment, resulting in an increase in stock prices. It well reflects in the real world. For example, when the Dow Jones index rises from 6600 of 2009 to 16000 of 2013, the growth of GDP is 4.1% at the first three quarters of 2013 and then reaches new height since two and a half years. These results are consistent with the results of theoretical derivation of the monetary transmission mechanism, that is, the rise in stock prices will boost output.

Figure 2. *The wavelet coherency and phase difference between the U.S. output and stock prices*

The y-axis refers to the frequencies (measured in mouths); the x-axis refers to the time period over the period 1986:1-2015:3. The color bar on the right side corresponds to the strength of correlation at each frequency.

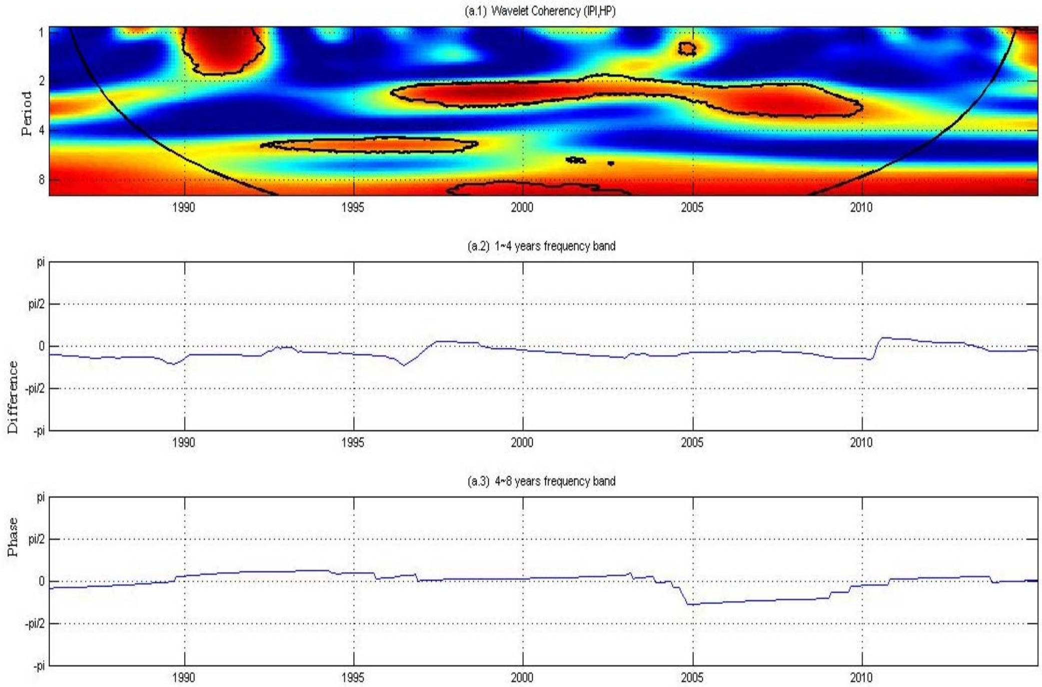


3.3. The relationship between U.S. output and house prices

Figure 3 shows that the relationship between the U.S. output and house prices is nonlinear and exhibits positive correlation. In the period 1990-1992, we first find that they show a obvious coherency of closes to 1 across the 1-2 year frequency band, implying a high degree of positive co-movement and the series of output will vary with our changes in house prices in the short time, which largely contradicts with Demary (2010) and Wendy et al. (2013), who suggest the real house prices affect output. This result is realistic that after a period of economic expansion in the 1980s, the Gulf War and the 1990 oil prices increase weakened the estate economy, leading to a period of brief slowdown in economic growth. Furthermore, we will read that house prices effect output in the short run during 1994-2010. Because the increase of house prices simultaneously increases the value of wealth of home owners. The increase of housing wealth can promote household consumption, which also contributes to economic growth. We also see that output effects house prices in the long run in the period 1994-2004. Furkan et al. (2014) present a reason to explain this relationship, that is, when the economy is in upswing, firms which have a job qualifies for cheap mortgage loan need more office space. This will trigger the demand for housing and then will translate into an increase in house prices. From 2004-2010, we, however, obtain that house prices lead output in the long run, that is, the experience of the financial crisis and Great Recession pushes the real house prices down and then provides the most vigorous response of the long-term variety of output in this period. The real house prices lead output for an extended period prior to the Great Recession. In addition, the cumulative effect of the real house prices on output proves positive and of long duration. Generally speaking, this results show that significant causality from the house prices to real GDP occurs more frequently than significant causality from real GDP to the real house prices. These results show that while the real house prices generally leads real output, both during expansions and recessions, significant feedback effects from the real output onto the real house prices. These findings occur especially during periods of volatility such as the brief recession in the 1990s, as well as, the recent financial crisis and Great Recession. These results are consistent with the results of theoretical derivation of the monetary transmission mechanism, higher house prices will lead to higher output.

Figure 3. *The wavelet coherency and phase difference between the U.S. output and house prices*

The y-axis refers to the frequencies (measured in mouths); the x-axis refers to the time period over the period 1986:1-2015:3. The color bar on the right side corresponds to the strength of correlation at each frequency.

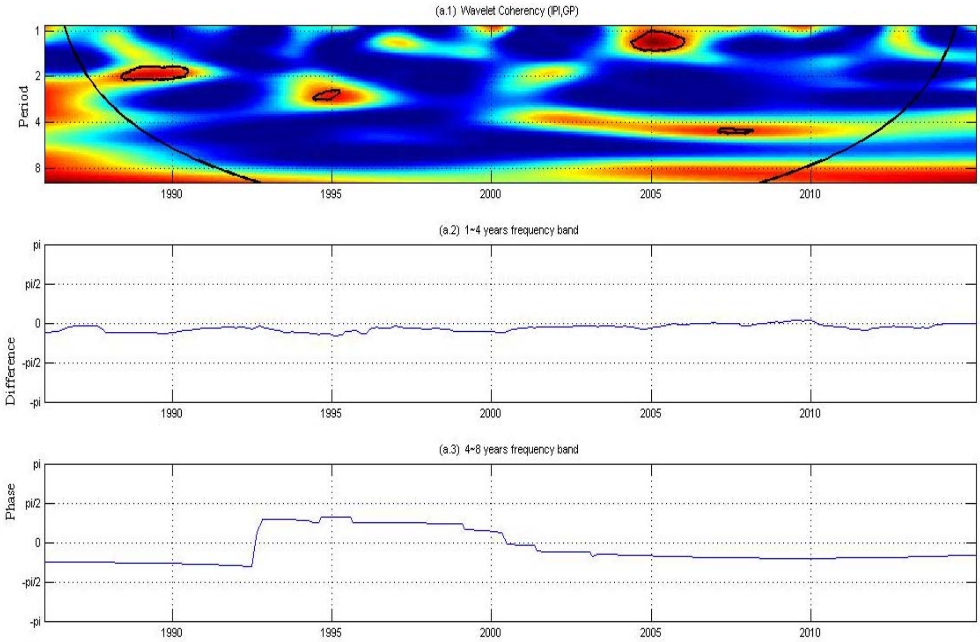


3.4. The relationship between U.S. output and gold prices

Figure 4 shows positive correlation and strong co-movement between the U.S. output and gold prices. More specifically, from 1987-1990,2004-2006,2007-2008 and 2013-2014, the two economic variables show an average coherency of 0.9 across the 1-2 year frequency band and indicated by the phase difference between $-\pi/2$ and 0 , implying gold prices affects the U.S. output in the short run. This result is consistent with the results of theoretical derivation of the monetary transmission mechanism, that is, higher gold prices will cause gold output. In addition, Manu and Rajnish (2012) obtain a similar conclusion, that is, the gold price is only moderately correlated with the U.S. GDP.

Figure 4. *The wavelet coherency and phase difference between the U.S. output and gold price*

The y-axis refers to the frequencies (measured in mouths); the x-axis refers to the time period over the period 1986:1-2015:3. The color bar on the right side corresponds to the strength of correlation at each frequency.



4. Conclusion

This paper employs wavelet analysis to research the relationship between the U.S. output and asset prices including gold prices, oil prices, house prices and stock prices using the U.S. monthly data ranging from 1986:01 to 2015:03. Wavelet analysis allows a simultaneous assessment of co-movement and causality between the every two series in both the time and frequency domains. More specifically, from the time domain, the output and asset prices including oil prices, stock prices and house prices exhibit positive co-movement in the most of the sample period. However, the relationship between output and gold prices is a positive correlation for only a few years. From the frequency domain, the output and stock prices, house prices correlate with each other at the short, medium and long run horizon. In addition, the results implies that combining output and oil prices achieves diversification generally at the short and medium run horizon, output and gold prices at the short run horizon.

These findings provide a more complete picture of the relationship between the U.S. output and asset prices over time and frequency domain, offering important implication to achieving economic growth and economic sustainability for policymakers and practitioners. That is, on one hand, development of the oil, stock, estate and gold market might be an efficient tool to stimulate economic growth and economic sustainability. On the other hand, it is necessary to avoid the over-heating of the economy in response to any positive asset prices shock that may raise the volatility of future GDP growth. More specifically, when there is a long-term relationship between assets prices and output, and we analyse the change of output in some years, we don't ignore the lag effect and structural changes between the relevant variables in earlier years and policymakers have to distinguish any asset bubble in earlier years to avoid much larger bubble burst in the future. In addition, a sustainable price can be the long-run equilibrium price. An equilibrium price is determined by macro fundamentals. The fundamentals of these assets prices include economic output. If there is a relationship in the short run between variables, implying that we should focus on a short time horizon so as to effectively judge main economic variables that affect the output in this period, and then we can more effectively interpret the change of output and fiscal policy might be more effective in formulating measures about output and it is helpful for economic sustainability.

Notes

(1) We know it from US Business Cycle Expansions and Contractions, NBER, accessed August 9, 2012.

(2) Such as Threshold VAR (TVAR), factor vector autoregressive models and threshold cointegration tests, etc. (Andrea and Claudio, 2010; Nazif and Ozelm, 2013; Kakali and Sajal, 2014).

(3) Feature extraction simplifies the resources required to describe a large set of data accurately. The self-similarity of a time series means the series exhibits long-term dependence (i.e., the whole series possesses the same shape, such as wave and cycle, as one or more of its parts). Taking advantage of feature extraction and self-similarity detection, the CWT extracts the local amplitudes of a time series in time and frequency domains. Then, the ensuing wavelet coherency and phase difference tools measure whether and how the local amplitudes of two time series correlate, and which one leads.

(4) In wavelet theory and practice, various types of mother wavelets exist for various purposes, such as the Haar, Morlet, Daubechies, Mexican hat and so on wavelets.

(5) Without smoothing, the squared wavelet coherence would always equal 1 at any frequency and time. Smoothing is achieved by convolution in time and frequency; see Torrence and Compo (1998) for details.

(6) As a measure of economic activity we use the lag of Gross Domestic Product. Since GDP figures are not available on a monthly basis, the monthly GDP is interpolated through the monthly industrial production index. In addition, the interpolation of GDP into monthly frequency using industrial production index may lead to exclusion of valuable information and measurement errors in the estimates. In order to check the robustness of the results obtained with interpolated GDP, the model is re-estimated with total industrial production index.

(7) Following the Bredin et al. (2010) and we use crude oil prices of West Texas Intermediate (WTI) - Cushing, Oklahoma as the initial data(expressed in U.S. dollars per barrel) we want to analysis. Because Oklahoma is the main crude storage place of United States. We obtain this data from http://research.stlouisfed.org/fred2/ series/DCOILWTICO/downloaddata.

(8) This gateway address is http://www.econ.yale.edu/~shiller/data.htm.

(9) We use Median Sales Price for New Houses Sold (expressed in U.S. dollars) in the United States.

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